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STS: Robotics and Virtual Worlds for wheelchair users - from ideas to reality: Innovation, Training, and Roadmap to Market (The ADAPT project)

Artificial intelligence for safe assisted driving based on user head movements in robotic wheelchairs

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Background

Wheelchairs users don't always have the ability to control a powered wheelchair using a normal joystick due to factors that restrict the use of their arms and hands. For a certain number of these individuals, which still retain mobility of their head, alternative methods have been devised, such as chin-joysticks, head switches or sip-and-puff control. Such solutions can be bulky, cumbersome, unintuitive or simply uncomfortable and taxing for the user. This work presents an alternative head-based drive-control system for wheelchair users.

Method used

Making use of the advancements in the deep-learning field, we have developed a drive-control solution based on two popular neural network models, which make use of a low-cost RGB camera to track that user's head an estimate its position and orientation. The user's head movements are translated to drive commands by which a user is able to control the speed and direction of the wheelchair movement. This control system works on top of our collision avoidance algorithm which adds an extra level of safety and prevents mishaps that could occur from any unwanted input. Head-tracking is achieved in two stages. The first stage uses the popular YOLO deep-learning object detection algorithm which we have re-trained specifically for face detection. The second stage uses a residual neural network (Resnet), re-trained specifically for estimating head pose. The YOLO network detects the user's face from the camera stream, which is then extracted from the image. The face detected is subsequently passed to the Resnet neural network, which outputs an estimation of the yaw and pitch of the head. These two outputs are translated into drive commands, forward-backward for pitch, and left-right for yaw. The system runs under the ROS (Robot Operating System) framework and all processing is achieved using a Jetson TX2 board, an embedded AI computing device with a CUDA enabled NViDIA GPU which is powered from the wheelchair's batteries.

Key results

Trials were conducted in a simulated environment with a joystick in-the-loop setup as baseline for evaluation, and an RGB camera for head-tracking. Both setups were tested with and without collision avoidance. With the exception of expert users of the head-tracking system, who completed the course without collisions, first-time users did not successfully pass the course. With the collision avoidance system, all participants completed the course without collisions both using head-tracking and joystick. Time to completion using head-tracking was 70.16% (± 25.78%) higher than using the standard joystick with no anti-collision. When driving with the standard joystick, the collision avoidance system introduced a 22.75% (±14.56%) increase in time.

Conclusion

The system demonstrates the practicality of using innovative deep-learning artificial intelligence coupled with a collision avoidance system for head-controlled driving of powered wheelchairs. This approach could prove preferable to currently available solutions because of its simplicity and efficiency. Additionally, input from the head-tracking system could be redirected, in order to control a tablet or smartphone, or send commands to a smart home or other Internet of Things (IoT) devices.

Tweetable abstract

This work demonstrates the feasibility of driving a smart powered wheelchair using head tracking based on computer vision and deep learning artificial intelligence algorithms implemented on an NViDIA Jetson TX2 microprocessor board.